Teaching Geosciences with Visualizations: Using, Images, Animations, and Models Effectively
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What is the impact of scientific visualizations on understanding of Earth processes?

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I am a geophysicist with research interests in design and development of technology-based curriculum to promote exploration of large geoscience datasets. Out of that experience, I have also begun to explore the development of spatial abilities in relation to working with visualizations of geoscience objects and processes, identification and remediation of scientific misconceptions, and knowledge acquisition. The focus of my work has been on students in high school through graduate school and my approach is that of a pragmatist trying to improve my teaching and in turn improve my students' learning potential.

Over the past four years, the SAGUARO team developed a series of GIS-based investigations of Earth processes for high school and college students. Our curriculum promotes inquiry of large data sets to relate patterns observed to the processes behind them. Because it is technology-driven and the technology requires a base level of expertise by the learner, the inquiry is guided; however, there are opportunities for students to freely investigate the data and relationships independently.

In developing the resources, we conducted extensive field tests and usability studies to determine the appropriate level of guidance needed on the technology, identify student misconceptions and measure knowledge acquisition. Through that process, I observed a number of things that I would like to investigate further, although I suspect some of the answers to my questions are already in the research literature.

<u>Is it easier or more difficult to interpret shaded relief maps than contoured maps? Contour maps with color increments or line increments? What interventions are most effective in helping students read maps?</u>

In our curriculum we have routinely used shaded relief maps or contour maps in which elevation increments were color coded rather than depicted with contour lines. In any case, significant numbers of students had difficulty recognizing the topographic features on the map. This is not unexpected and has been documented by many researchers. Interventions that included having students draw topographic profiles across different regions, explore block diagrams with topographic and related subsurface features, and view animations of slices through a block diagram to show how topography would look in a cross section addressed the problem for almost all students. Our approach was to add each of these interventions incrementally until we observed that all students were successful in interpreting the shaded relief map, but we do not know what the impact of any one of these interventions had on student perception and understanding of the of the topographic surface and the different mechanisms for representing it. We also do not know which of the three representations of topography, shaded relief, colored contour intervals or contour lines, is most effective in helping students read topographic maps.

<u>Can novice learners effectively interpret animations of processes that include two or more variables?</u>

This question arises from the use of an animation (deemed by a group of expert scientists to be the most accurate and complete representation they had found) of the tsunami created by the 1964 Alaska earthquake. The animation shows changes in sea level in the open ocean and near shorelines from Alaska to California due to the tsunami wave and normal changes in the tide levels over a 14-hour period. In addition to showing the wave propagation across the ocean, graphs of shoreline sea level changes display in “real-time” as the wave animation progresses. Testing of this animation on freshman through senior undergraduate level science majors revealed that many freshman could not identify the coastline nor the initiation point of the tsunami wave, upper classmen who were more familiar with the concept of a tsunami could identify and describe the initial movement of the tsunami wave out from its source region but were confused by wave patterns in which large tides interacted with the tsunami wave. Few students at any level could correlate the shoreline sea level changes with the tsunami and tidal wave patterns. Alternatively, simple animations of tsunami waves on a more local scale and of shorter duration (thus, tides played a relatively small role), and in which the topography of the shoreline was shown in 3D shaded relief were easily described and interpreted by these same students. Tversky et al, 2003 have shown that a series of static visuals are as effective in animations with identical information, so it is possible that this animation could be broken down into a series of graphics that run slower and have more symbols to guide the learners’ observations. But what are the challenges for interpreting still visuals or animated visuals that have multiple variables changing at the same time, such as the tsunami wave height and the tide wave height?

<u>How effective are 3D interactive models in helping learners visualize subsurface features such as the shape of a water table, fault zone, or magma body? What mental models need to be in place before these types of visualizations are effective?</u>

In our investigations of water resources, it was necessary for our students to gain an understanding of how a water table responds to long term over-drafting of an aquifer. Three-dimensional interactive visualizations extending from the ground surface (shown with street grids and topography) to well below the top of the current water table were created. The visualizations also showed the location of pumping wells, which were color-coded to show length of time they had been in operation. It also showed the water table surface 20 years ago and 50 years ago. From this, students were expected to be able to identify and describe the shape of the water table at each point in time, how it had changed between these time periods, and the relationship between length of operation of a well and the top of the water table, among other things.

Most students had great difficulty orienting themselves with the ground surface and projecting observations of subsurface features to the surface. The depiction of the wells seemed to distract them from clearly seeing the water surfaces. And the relationship between the length of time a well had been operating and the level of the water table was generally not observed by the students. Expert scientists, especially in extractive industries such as water, petroleum and minerals, increasingly use these visualizations. What is the key for students to begin interpreting such diagrams? What are the key elements necessary to guide the novice learner through these complex visualizations?

<u>Effective use of models, metaphors and analogies in teaching about Earth processes that occur over long time periods and scales not easily modeled in the laboratory.</u>
In my presentation at the workshop, I will show a number of examples of visuals, models and analogies commonly used in the geosciences to teach about Earth processes that occur over long time periods and scales not easily modeled in the laboratory. It is the only way in many cases to teach about these concepts. However, it is clear we are introducing misconceptions to our students that propagate to different concepts and processes in the geosciences. I am interested in determining how we can improve the current models, analogies and visualizations to address these misconceptions.

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